

**National Park Service Workshop
Persistent Organic Pollutants and Air Toxics
Monitoring Design Considerations: Contaminants in Fish and Wildlife**

Status and Trend Monitoring in Fish/Wildlife

POPs and mercury tend to bioaccumulate in higher trophic levels. Long-lived species (such as orcas) may reflect both recent and past exposure to contaminants, thus residues in these species may show a time lag when compared with trends in the abiotic environment (e.g., air sampling which changes rapidly). Terrestrial food webs (e.g., lichen-caribou-wolf) may accumulate different contaminants than marine systems (e.g., algae-zooplankton-fish-seal-polar bear) or accumulate contaminants at different rates. Potential sentinel species which might be appropriate for monitoring long-term trends include the following:

Marine mammals: seals, orcas, polar bears

Raptors: osprey, peregrine falcon, bald eagle

Marine and freshwater fish-eating birds: cormorants, seabirds, loons, mergansers

Predatory fish: northern pike, burbot, char species, lake trout, chinook or other salmon, marine benthic fish

Riverine/semi-aquatic mammals: river otter, mink

Invertebrates: mussels

Subsistence

Subsistence use is a very important issue in Alaska, with subsistence use patterns varying among communities depending upon species availability and cultural/traditional practices. Local importance and the probability of accumulating contaminants may be the most relevant considerations in selecting species. For example, while berries may be a locally important seasonal food item, they would likely have low levels of POPs, whereas marine mammal blubber could be a significant source of these compounds. Many predatory marine, anadromous and freshwater fish may accumulate significant contaminants loads and also are consumed frequently.

Anadromous fish - salmon (some whitefish, trout, char)

Marine fish - halibut, cod, flounder, rockfish, etc.

Resident fish - burbot, northern pike, char, whitefish

Seabird (eggs and some adults) - gulls, murres, other locally important species

Marine mammals - seals (bearded, spotted, ringed), whales (beluga, bowhead), walrus, polar bear

Large terrestrial game mammals - caribou, moose, deer

Bivalves : clams, mussels, chitons, limpets, etc.

Species	Tissue	Pro's	Con's	Potential Uses, Existing Data
Invertebrates				
Mussels (e.g., blue mussel)	Whole body (soft parts)	<p>Sessile</p> <p>Limited lifespan</p> <p>Important food item for many species</p> <p>Also useful for PAHs/petroleum (little metabolism of hydrocarbons)</p> <p>Subsistence item, surrogate for some other intertidal and subsistence species</p>	Limited to coastal areas	<p>Marine/Coastal pollution, subsistence</p> <p>Extensive database (NOAA, EPA, other nations) including many "mussel watch" type monitoring programs</p>
Zooplankton	Whole body	<p>Important food items in aquatic environments</p> <p>Ubiquitous</p>	<p>Community composition will differ with lake chemistry, biogeography, seasonality, time of day (vertical migration), etc.</p> <p>Some existing data (mostly marine), but not extensive</p> <p>Relevance to average citizen?</p>	Freshwater and marine systems
Benthic insects	Whole body	<p>Important food items in aquatic environments</p> <p>Fairly ubiquitous</p>	<p>Trophic differences (predators, shredders, collector-gatherers, etc.)</p> <p>Drift in streams</p> <p>Existing database limited</p> <p>Relevance to average citizen?</p>	Freshwater systems
Earthworms	Whole body	<p>Used in lab toxicity studies, residue studies at highly contaminated sites</p> <p>Used to calculate bioaccumulation factors</p> <p>Widespread distribution</p>	<p>Low on food chain</p> <p>Little/no contaminants database for natural sites</p> <p>Relevance to average citizen?</p>	Terrestrial systems

Freshwater Predatory Fish				
Northern Pike	Whole body Fillet Liver/kidney	Known to accumulate contaminants Wide geographic distribution Abundant in some parts of AK Sport and subsistence species Found in both lakes and rivers, lake populations not migratory Extensive database from Canada and U.S.	Not found in many western Parks Migratory in large river systems like the Yukon	Contamination in freshwater systems, sport and some subsistence use High mercury found in Canada and parts of northern U.S., good indicator species for monitoring mercury, but typically low OCs in pike muscle
Burbot	Liver	Liver accumulates organic contaminants Database for circumpolar region Subsistence species	Limited (northern) distribution: Alaska and Montana Migratory in large river systems	Contamination in freshwater systems, subsistence Canadian data: burbot liver have high PCBs and toxaphene relative to char, lake trout and whitefish muscle
Lake Trout	Whole body Fillet Liver/kidney	High lipid content Wide geographic distribution Represents local conditions Sport and subsistence species Fairly extensive database	Limited to lake systems, common in some parts of Alaska, but otherwise limited distribution Can live 50(+) years in some systems; implications for trend monitoring	Contamination in lake systems, subsistence and sport Canadian data: within a lake, age and fish weight significantly correlated with toxaphene concentration Among highest for mercury (along with Canadian pike and walleye)
Arctic char and dolly varden	Whole body Fillet Liver/kidney	Circumpolar distribution for char Coldwater habitats Landlocked Arctic char are an AMAP (Arctic Monitoring and Assessment Program) species	Limited to cold-water streams and lakes Within a species, trophic status can differ greatly with age and location	Contamination in freshwater systems, subsistence and sport High mercury in large landlocked Canadian char, mercury low in sea-run char Canadian fish results (lake trout and Arctic char) in general were quite variable
Native or	Whole body	Fairly ubiquitous; all Parks appear to	Species differ among Parks	Contamination in freshwater

introduced trout	Fillet Liver/kidney	have one or more species Rainbow trout used as toxicity test species, but less information on ambient residue concentrations	Within a species, trophic status can differ greatly Some anadromous populations	
Marine Fish				
Bottom fish (sole, flounder, halibut)	Whole body Fillet Liver/kidney	Wide distribution Associated with contaminated sediments	Limited to marine waters	Marine contamination Toxaphene most important OC in marine fish from Canadian Arctic. Highest OC's found in turbot (Greenland halibut) at levels 15-20X Arctic cod
Anadromous Fish				
Chinook salmon (or other Pacific salmon)	Whole body Fillet Liver/kidney	Marine predator High lipid content Highly important sport, commercial, subsistence species in Alaska, Pacific NW, California Possibly important vector for contaminants from marine to terrestrial systems	Oceanic range poorly understood Coastal distribution Not present in all Parks Reflects marine pollutant uptake Little existing data, but database growing	Reflects marine pollution trends, important for subsistence
Marine and Freshwater Birds				
Double crested cormorant	Eggs, feathers	Marine and some freshwater systems, consumes fish Know effects (eggshell thinning) Extensive database Wide geographic distribution	Many/most migratory Coastal distribution, and some large lakes, rivers or estuaries	Coastal contaminants
Seabirds (gulls, murre, etc.)	Eggs, feathers	Eggs easy to collect Represent different trophic levels and feeding guilds	Many migratory (at least in much of AK)	Marine contamination, gulls in some freshwater systems, subsistence (eggs) Glaucous gulls in Canada had OC

		Data from Canada, Europe, murre eggs from Bering Sea (AK), subsistence study in AK (gull eggs) Locally important subsistence food		levels 4-10X higher than thick-billed murre, black guillemot, northern fulmar, and black-legged kittiwakes. Total mercury also highest in gulls In Svalbard, Norway, gulls have highest contaminant levels of any animal (even polar bears)
Loons	Blood Feathers Eggs	Wide geographic distribution Eat fish Database for metals (lead, mercury) in blood, feathers (mercury)	Migratory	Contamination in freshwater systems In Canadian survey of contaminants in waterfowl and game birds, highest OC's found in piscivores like loons, values higher in eastern Canadian Arctic
Raptors				
Osprey	Eggs, feathers (for mercury)	Eats fish Known effects (eggshell thinning) Wide geographic distribution Not listed under ESA	Migratory in most areas (always migratory?) Widespread but rarely abundant	Indicator of contamination in freshwater and coastal ecosystems Studies of osprey in Pacific NW
Bald eagle	Eggs, feathers (for mercury)	Eats primarily fish, marine birds or carcasses in some locations Known effects (eggshell thinning) Extensive database in U.S. Wide geographic distribution Abundant in coastal Alaska	ESA listed in lower 48, Bald Eagle Protection Act requirements Not abundant in all Parks Migratory in many areas	Indicator of contaminants in coastal ecosystems, large rivers, and lakes USGS-BRD has studied eagles in Aleutians. Eagles on Kiska Island (western edge of range) had highest DDE and mercury values, and eagles on Kiska showed reduced reproductive success. In general PCBs correlated best with military presence, DDT may reflect food web differences (consuming birds vs. fish)
Peregrine falcon	Eggs, feathers (for mercury)	Preys on birds Known effects (eggshell thinning)	Highly migratory (i.e., South and Central America) Widespread but rarely abundant,	Indicator of contaminants in avian food web FWS has long-term data set ('79-

		Extensive database Wide geographic distribution No longer listed under ESA	patchy distribution Not found in all Parks	'95) for two sub-species nesting in AK. Organochlorines declined with time, but PCBs declined more slowly than pesticides like DDE Mercury has not declined, and may have increased. Mercury values in some cases approach reproductive thresholds
Riverine/Fish Eating Mammals				
River Otter	Liver/kidney Blood?	Widespread distribution Riverine predator Non-migratory	Absent or rare in some Parks Typically sample organs (lethal)	Contamination in freshwater systems Known impacts from Pacific NW (Henny et al.). Young male otters from polluted areas had smaller testes, baculum
Mink	Liver/kidney Blood?	Widespread distribution Eat small mammals and fish (both marine and terrestrial food webs) Commonly used for toxicity studies (captive breeding) Extremely sensitive to PCBs and mercury, among most sensitive mammals known Data from Canada and Great Lakes Non-migratory	Absent or rare in some parks Typically sample organs (lethal)	Contamination in freshwater and terrestrial systems In Canada, more highly chlorinated PCB congeners predominant. Found decreasing DDT and PCBs with increasing latitude. Localize sources of metals most important Mink from Northwest Territories had lower OC (DDT, PCB) levels compared with other part of North America. Concentrations lower than reproductive thresholds
Marine Mammals				
Harbor seal	Blubber	Contaminants database Extensive distribution	Coastal areas Not used as much for subsistence	Coastal pollution
Ringed Seals, other seals	Blubber Flesh	Subsistence (bearded, spotted and ringed are primary subsistence species)	Limited to coastal areas of Alaska, some species associated with ice edge	Marine pollution, subsistence Canadian ring seal data: PCBs,

		<p>Extensive circumpolar database (primarily for ringed seals)</p> <p>Ringed seals don't move as much as some other seal species (more limited range)</p> <p>Ringed seals are an AMAP species</p>		<p>DDTs and chlordanes more important than toxaphene. Hudson Bay ring seals most highly contaminated</p> <p>Methyl-mercury did not differ from western to eastern Canada</p> <p>OC concentrations increase with age in males, but not in females</p>
Polar Bear	<p>Fat</p> <p>Flesh</p> <p>Liver/Kidney</p>	<p>Top predator in Arctic marine food web; feed primarily on ringed seals, some bearded seals</p> <p>Canadian bears at trophic level 5; biomagnification up to 17,000 times particulate organic matter in sea water</p> <p>Circumpolar distribution</p> <p>Fairly extensive database circumpolar</p> <p>Some subsistence use</p> <p>AMAP species</p>	<p>Limited to Northern Alaska (not applicable to most Parks)</p> <p>Very large home range</p>	<p>Marine pollution, subsistence</p> <p>Initial analysis of FWS data on Alaskan bears suggests that DDT and PCBs are lower in AK compared to Europe and eastern Canada, but HCH is higher in AK. Similar findings in Canadian bears. Suggests HCH source from Asia rather than North America</p> <p>In Canada; OC's highest in southeastern part of range (Hudson Bay) and lowest OC's in northwest (Beaufort Sea). Relatively high in PCBs and oxychlordanes. Total-PCBs up to 46% higher in males vs. females</p> <p>Metals (liver): cadmium, mercury and selenium increase with age. Cadmium higher in eastern Canada, while mercury and selenium were 7-10X higher in western Canada, probably reflecting sedimentary geology of area</p>
Walrus	<p>Blubber</p> <p>Flesh</p>	<p>Circumpolar distribution</p> <p>Important subsistence item</p>	Limited to Bering/Chukchi Seas	<p>Walrus typically low in OC compounds (primarily benthic feeders). Some Canadian walrus had higher OC's since prey more on seals.</p> <p>Walrus have high metals (e.g.,</p>

				cadmium) in kidney
Beluga	Blubber Flesh	Circumpolar distribution Fairly extensive database Subsistence use extensive	Limited to parts of Alaska (Cook Inlet, Bering Sea, Chukchi Sea, Beaufort Sea)	Marine pollution, subsistence Canada: toxaphene is dominant compound of concern, and significantly higher (3X) in eastern Canada, lower in Beaufort Sea In AK: Cook Inlet beluga had lower OC's compared with more northern stocks in Bering/Chukchi and Beaufort seas Metals in Canadian belugas: highest mercury in western Arctic (excluding St. Lawrence), but highest cadmium in eastern Canada Mercury almost 100% methyl-mercury in beluga, and regularly exceeded Canadian fish advisory levels. Total mercury correlated with animal age
Orca	Blubber	Top predator in marine environment	Can live 50(+) years in some systems; implications for trend monitoring Not a subsistence species	Marine pollution Pods differ in feeding ecology (residents vs. transients). Transients consume more marine mammals and are among most highly contaminated marine mammals. Resident pods eat more salmon, and are less contaminated
Large Terrestrial Game Animals				
Caribou	Flesh Liver/Kidney	Subsistence Circumpolar data exist Charismatic mega-fauna; relevant to Park visitors In Canadian caribou, more volatile but less persistent OC compounds	Migratory Limited to Alaska	Terrestrial food web Subsistence; OC's at lower levels, but major food source for some communities Organochlorines typically lower than marine mammals. In Canada, significant increase in OC's from

		<p>(such as HCH, HCB) predominate, reflecting air concentrations</p> <p>Existing radionuclide database (levels in Canadian caribou 4-10 times lower now, compared with 1960's)</p>		<p>west to east (reflect industrialization). Dioxins low; PCBs contribute most to TEQ (a measure of the toxicity of dioxin-like compounds)</p> <p>Metals in kidney (e.g., cadmium) can be a concern. Mercury low in Canadian caribou, no spatial pattern</p>
Moose	Flesh Liver/Kidney	<p>Widespread distribution</p> <p>Charismatic mega-fauna; relevant to Park visitors</p> <p>Not as migratory as caribou</p> <p>Circumpolar database (e.g. northern Europe)</p>	Common in some parts of AK, but absent or rare in some other Parks	<p>Terrestrial food web</p> <p>Subsistence</p> <p>Organochlorines typically lower than marine mammals. Metals in kidney (e.g., cadmium) can be a concern</p>
Surrogates				
Lichens		<p>Accumulates air toxics (metals, radionuclides)</p> <p>Sessile</p> <p>Circumpolar database</p> <p>Base of food chain for caribou</p>	Useful for POPs ?	Terrestrial and air toxics (particularly metals and radionuclides)
Sediments		Accumulates contaminants (both metals and POPs)	Contamination is patchy, dependant on organic carbon and other variables	Freshwater and marine pollutants
SPMDs		Surrogate for species with high lipid content	Can deploy anywhere	Freshwater, marine, air pollutants